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(54) Title: USE OF MoO_3 AS CORROSION INHIBITOR, AND COATING COMPOSITION CONTAINING SUCH AN INHIBITOR

(57) Abstract: The subject of the invention is the user of MoO_3 as a corrosion inhibitor, and an anti-corrosion coating composition for metal parts, characterized in that it comprises: - at least one particulate metal; - an organic solvent; - a thickener; - a silane-based binder, preferably carrying epoxy functional groups; - molybdenum oxide (MoO_3); - possibly a silicate of sodium, potassium or lithium, and; - water.

"USE OF MoO_3 AS CORROSION INHIBITOR, AND COATING COMPOSITION CONTAINING SUCH AN INHIBITOR"

The object of the present invention is to develop an anti-corrosion coating for metal parts, preferably a coating free of hexavalent chromium, which is endowed with improved anti-corrosion properties.

The invention applies to metal parts of any type, in particular made of steel or cast iron, which need to have good corrosion behaviour, for example because of their application in the motor-vehicle industry. The geometry of the parts to be treated is of little importance as long as the anti-corrosion compositions may be applied by reliable and industrializable processes.

One of the objects of the present invention is in particular to improve the anti-corrosion properties of parts treated without using a composition based on hexavalent chromium in the formulation of the coatings.

Many anti-corrosion treatment solutions based on hexavalent chromium have been proposed to date. Although they are generally satisfactory with regard to the protection of treated metal parts, they are, however, becoming increasingly criticized because of their consequences with regard to the toxic risks that they entail and in particular because of their adverse consequences for the environment.

As a consequence, various anti-corrosion treatment compositions free of hexavalent chromium have been recommended. Some of these compositions are based on a particular metal, such as zinc or aluminium. However, when such compositions are in the form of an aqueous dispersion their stability is limited. This precludes long preservation and storage times.

Within the context of the present invention, the Applicant has discovered that it is possible to improve the anti-corrosion properties and the stability of various anti-corrosion coating compositions by incorporating thereinto molybdenum oxide MoO_3 as corrosion inhibitor.

Hitherto, the use of molybdenum oxide MoO_3 as a corrosion inhibitor in systems of aqueous phase has not been known. Certain molybdates, i.e. MoO_4^{2-} ions, have already been presented as corrosion inhibitors. However, the Applicant has been able to show that in a certain number of conventional anti-corrosion compositions the addition of a molybdate, for example zinc molybdate, in no way improves its properties.

The present invention relates more particularly to the use of molybdenum oxide MoO_3 as an agent for enhancing the anti-corrosion properties of a coating composition based on a particulate metal containing zinc or a zinc alloy in aqueous phase. This finding has even been extended to composition containing hexavalent chromium. This is another object of the invention.

Without in any way wishing to be limited to such an interpretation, it seems that in the particular case of an anti-corrosion coating composition based on a particulate metal, the presence of molybdenum oxide MoO_3 makes it possible to improve the control of the sacrificial protection exerted by the particulate metal in suspension in the composition.

According to one particular feature, the particulate metals have a lamellar form, the thickness of the flakes being comprised between 0,05 μm and 1 μm and having a diameter equivalent (D_{50}) measured by laser diffraction comprised between 5 μm and 25 μm the subject of the invention is more particularly the use of molybdenum oxide MoO_3 in a composition containing zinc in aqueous phase.

According to another feature of the invention, the molybdenum

oxide MoO_3 is used in an essentially pure orthorhombic crystalline form, having a molybdenum content greater than approximately 60% by mass.

Advantageously, the molybdenum oxide MoO_3 will be used in the anti-corrosion compositions in the form of particles having dimensions of between 1 and 200 μm.

More specifically, the subject of the present invention is anti-corrosion coating compositions for metal parts, which comprise:

- at least one particulate metal;
- an organic solvent;
- a thickener;
- a silane-based binder, preferably carrying epoxy functional groups;
- molybdenum oxide (MoO_3);
- possibly a silicate of sodium, potassium or lithium, and ;
- water.

The relative proportions of the various constituents in such a composition may vary widely. However, it has turned out that the content of molybdenum oxide MoO_3 is preferably between 0.5 and 7% and even more preferably in the region of 2% by weight of the total composition.

The particulate metal present in the composition may be chosen from zinc, aluminium, chromium, manganese, nickel, titanium, their alloys and intermetallic compounds, and mixtures thereof. It should be pointed out here that if the recommended coating composition is preferably free of Cr^{VI}, it may nevertheless contain a certain proportion of metallic chromium. In practice, it has turned out that the presence of zinc is highly desirable.

Advantageously, the particulate metal content is between 10% and 40% by weight of metal with respect to the weight of the composition.

Preferably, the anti-corrosion coating composition according to the invention contains zinc and/or aluminium, and preferably comprises zinc.

As indicated above, this type of composition is mainly of aqueous nature and therefore preferably contains from 30% to 60% by weight of water. The composition may nevertheless be enriched by the presence of an organic solvent, preferably a water-soluble organic solvent, which makes it possible to improve the anti-corrosion performance of the composition. For this purpose, the composition will contain, for example, from 1% to 30% by weight with respect to the total composition. However, it seems to be important not to exceed this organic solvent content of approximately 30%.

In an advantageous embodiment of the invention, the composition will make use of an organic solvent, for example consisting of a glycol ether, in particular diethylene glycol, triethylene glycol and dipropylene glycol.

According to another feature of the present invention, the anti-corrosion composition also contains from 0.005% to 2% by weight of a thickening agent, in particular of a cellulose derivative, more particularly hydroxymethylcellulose, hydroxyethylcellulose, hydroxypropylcellulose, hydroxypropylmethylcellulose, xanthan gum or an associative thickener of the polyurethane or acrylic type.

The composition of the present invention may also contain mineral rheologic agents of the silica or organophilic clays type.

Such a composition also makes use of a binder, preferably an organofunctional silane, used in an amount of 3% to 20% by weight. The organofunctionality can be represented by vinyl, methacryloxy and amino, but is preferably epoxy functional for enhanced coating performance as well as composition stability. The silane is advantageously easily dispersible in

aqueous medium, and is preferably soluble in such medium. Preferably, the useful silane is an epoxy functional silane such as beta-(3,4-epoxycyclohexyl) ethyltrimethoxysilane, 4(trimethoxysilyl) butane-1,2 epoxide or γ-glycidoxypropyl-trimethoxysilane.

Finally, the anti-corrosion coating compositions according to the invention may also contain, in addition to the aforementioned organic solvent, up to a maximum amount of approximately 10% by weight of white spirit so as to improve the ability of the anti-corrosion compositions to be applied to the metal parts by spraying, dipping or dip-spinning.

Advantageously, the composition may also contain a silicate of sodium, potassium or lithium, preferably in an amount comprised between 0,05 % to 0,5 % by weight.

Naturally, the present invention also relates to anti-corrosion coatings which are applied to the metal parts using the aforementioned compositions, being applied by spraying, spinning or dip-spinning followed by a curing operation at a temperature of between 70°C and 350°C for a cure time of around 30 minutes.

According to an advantageous embodiment, the anti-corrosion coating will result from an application operation involving, prior to the curing operation, an operation of drying the coated metal parts, preferably at a temperature of around 70°C for approximately 20 minutes. Under these conditions, the thickness of the coating thus applied is between 3 μm and 15 μm and preferably between 5 μm and 10 μm.

In the examples presented hereinbelow for comparative purposes, various types of corrosion inhibitor were tested within the context of the present study, which was carried out in order to improve the anti-corrosion properties of various compositions and in particular of the reference composition called GEOMET® which has been described in

US 5 868 819 herein incorporated by reference.

These were the main commercially available corrosion inhibitors. They have been listed below by broad chemical category, specifying each time the origin of the product together with its name and its composition.

- Modified zinc phosphates:

Supplier: Heubach:

HEUCOPHOS® ZPA:	hydrated zinc aluminium orthophosphate
HEUCOPHOS® ZMP:	hydrated zinc molybdenum orthophosphate
HEUCOPHOS® SAPP:	hydrated strontium aluminium polyphosphate (SrO: 31%; Al_2O_3: 12%; P_2O_5: 44%; $MgSiF_6$: 0.3%)
HEUCOPHOS® SRPP:	hydrated strontium aluminium polyphosphate (SrO: 28%; Al_2O_3: 12%; P_2O_5: 42%)
HEUCOPHOS® ZCP:	hydrated zinc calcium strontium silicate orthophosphate
HEUCOPHOS® ZCPP:	hydrated zinc calcium aluminium strontium silicate orthophosphate (ZnO: 37%; SrO: 5%; Al_2O_3: 3%; P_2O_5: 18%; CaO: 14%; SiO_2: 14%)
HEUCOPHOS® CAPP:	hydrated calcium aluminium silicate polyphosphate (Al_2O_3: 7%; P_2O_5: 26%; CaO: 31%; SiO_2: 28%)

Supplier: Devineau:

ACTIROX® 213:	zinc iron phosphates (ZnO: 66%; PO_4: 48%; Fe_2O_3: 37%)

Supplier: Lawrence Industries:

HALOX® SZP 391:	zinc calcium strontium phosphosilicate
HALOX® CZ 170:	zinc orthophosphate

Supplier: Tayca:

K WHITE® 84: aluminium triphosphate (ZnO: 26.5 to 30.5%; Al_2O_3: 9 to 13%; P_2O_5: 36 to 40%; SiO_2: 11 to 15%)

- Molybdates

Supplier: Devineau:

ACTIROX® 102: zinc molybdates coupled to zinc-phosphate-modified agents (ZnO: 63%; PO_4: 46%; MoO_3: 1%)

ACTIROX® 106: zinc molybdates coupled to zinc-phosphate-modified agents (ZnO: 67%; PO_4: 46%; MoO_3: 1%)

Supplier: Sherwin Williams:

MOLY WHITE® MAZP: ZnO, $CaCO_3$, $Zn_3(PO_4)_2$, $CaMoO_4$

MOLY WHITE® 212: ZnO, $CaCO_3$, $CaMoO_4$

Sodium molybdate: Na_2MoO_4

- Borates

Supplier: Buckman:

BUTROL® 23: calcium metaborate

BUSAN® 11M2: barium metaborate

Supplier: Lawrence Industries:

HALOX® CW 2230: calcium borosilicate

- Calcium-doped silica

Supplier: Grace:

SHIELDEX® AC5

- Zinc salts

Supplier: Henkel:

ALCOPHOR® 827: organic zinc salt

- Organic inhibitors

Supplier: Ciba-Geigy:

IRGACOR® 1930:	complex of zirconium and 4-methyl-γ-oxobenzenebutanoic acid
IRGACOR® 1405:	4-oxo-4-*p*-tolybutyric acid with 4-ethylmorpholine
CGCI® (IRGACOR 287):	polymeric amine salts

Supplier: Lawrence Industries:

HALOX FLASH® X:	boric acid, phosphoric acid, triethanolamine salts, 2-dimethyl-aminoethanol

◆ Zinc passivators

Supplier: Ciba-Geigy:

IRGAMET® 42:	2,2 [[(5-methyl-1H-benzotriazol-1-yl)methyl]imino]bisethanol
IRGAMET® BTA M:	1H-benzotriazole.

EXAMPLE 1

The standard reference GEOMET® composition corresponds to:

Deionized water	38.60%
DPG	10.29%
Boric acid	0.65%
SYMPERONIC® NP4	1.51%
SYMPERONIC® NP9	1.64%
SILQUEST® A187	8.66%
Zinc*	32.12%
Aluminium**	5.08%
SCHWEGO FOAM®	0.4%
NIPAR® S10	0.71%
AEROSOL® TR70	0.53%

* Lamellar zinc in the form of an approximately 95% paste in white spirit : zinc 31129/93 of ECKART WERKE ;

** Lamellar aluminium in the form of an approximately 70% paste in DPG : CHROMAL VIII® of ECKART WERKE.

To carry out the various comparative experiments on the aforementioned inhibitors, different baths were obtained by adding 1 g of inhibitor to 9 ml of water, the dispersion being maintained for 1 hour, then the mixture was added to 90 g of the aforementioned standard GEOMET® composition and then stirred for 3 hours.

The first layer of this composition to be tested was applied using a No. 38 Conway bar. The drying was carried out at 70°C for approximately 20 minutes and then the curing was carried out at 300°C for approximately 30 minutes.

The second layer was applied using an identical protocol.

The panels thus treated were then tested in a salt spray. The salt spray resistance results for the various coatings tested are given in the table below.

TABLE 1

Nature of the inhibitor	Name of the inhibitor	Number of hours in salt spray without red rust
Reference	GEOMET	112
	GEOMET + ZPA	134
	GEOMET + ZMP	122
	GEOMET + SAPP	66
	GEOMET + SRPP	66
Modified zinc phosphates	GEOMET + ZCP	66
	GEOMET + ZCPP	88
	GEOMET + CAPP	66
	GEOMET + ACTIROX 213	66
	GEOMET + HALOX 391	66
	GEOMET + K WHITE 84	88
	GEOMET + ACTIROX 102	66
	GEOMET + ACTIROX 106	88
Molybdates	GEOMET + MW 212	88

	GEOMET + MW MZAP	88
	GEOMET + Na_2MoO_4	66
Borates	GEOMET + BUTROL	44
	GEOMET + BUSAN	112
	GEOMET + HALOX 2230	66
Various	GEOMET + SHIELDEX	112
	GEOMET + ALCOPHOR 827	66
	GEOMET + IRGACOR 1930	88
	GEOMET + IRGACOR 1405	88
	GEOMET + CGCI	88
	GEOMET + HALOX FLASH X	66
	GEOMET + IRGAMET 42	44
	GEOMET + IRGAMET BTAM	66
Invention	GEOMET + MoO_3*	518

* MoO_3 : POR from CLIMAX Company

In addition, the more particular salt spray resistance results as a function of the age of the bath, and therefore of its stability at 4°C and 20°C respectively, are given in the appended Figures 1 and 2.

Both these figures show very clearly that, in each case, on the one hand, the anti-corrosion performance of the composition containing molybdenum oxide MoO_3 is markedly improved and that, on the other hand, the anti-corrosion performance is maintained better over time when molybdenum oxide is added to the composition.

EXAMPLE 2

Two other types of comparative experiments were carried out, one on a GEOMET® composition and the other on a DACROMET® composition based on hexavalent chromium.

The formulations of these compositions are given in the tables below.

TABLE 2

GEOMET®

Raw materials	Concentrations in % without MoO_3	Concentrations in % with MoO_3
Deionized water	38.60	37.83
DPG	10.29	10.08
Boric Acid	0.65	0.64
SYMPERONIC NP4®	1.51	1.48
SYMPERONIC NP9®	1.64	1.61
SILQUEST® A187	8.66	8.47
Zinc*	32.12	31.48
Aluminium**	5.08	4.98
SCHWEGO FOAM®	0.4	0.21
NIPAR® S10	0.71	0.70
AEROSOL® TR70	0.53	0.52
MoO_3***	0	2

* Lamellar zinc in the form of an approximately 95% paste in white spirit : Zinc 31129/93 of ECKART WERKE ;

** Lamellar aluminium in the form of an approximately 70% paste in DPG : CHROMAL VIII® of ECKART WERKE.

***MoO_3 : POR from CLIMAX Company

SYMPERONIC®: nonionic surfactants
SILQUEST® A187: γ-glycidoxypropyltrimethoxysilane
SCHWEGO FOAM®: hydrocarbon-type antifoam
NIPAR® S10 : nitropropane
AEROSOL® TR70: anionic surfactant.

TABLE 3

DACROMET®

Raw materials	Concentrations in % without MoO_3	Concentrations in % with MoO_3
Deionized water	47.86	44.90
DPG	15.95	15.63
PGME acetate	1.56	1.53
Chromic acid	3.81	3.73
REMCOPAL® 334	0.72	0.71
REMCOPAL® 339	0.72	0.71
Zinc*	23.61	23.14
Aluminium**	3.06	3.00
Boric acid	1.30	1.27
ZnO	1.41	1.38
MoO_3***	0	2

* Lamellar zinc in the form of an approximately 95% paste in white spirit : Zinc 31129/93 of ECKART WERKE ;

** Lamellar Aluminium in the form of an approximately 70% paste in DPG : CHROMAL VIII® of ECKART WERKE.

*** MoO_3 : POR from CLIMAX Company

REMCOPAL®: nonionic surfactants.

It should be noted that the molybdenum oxide powder was each time introduced into the GEOMET® or DACROMET® bath by dusting. The bath was homogenized by stirring using a dispersive blade at 450 revolutions per minute.

The anti-corrosion compositions tested were applied to 10 cm x 20 cm cold rolled low carbon steel panels by coating using the Conway bar, followed by predrying at 70°C during about 20 minutes, and then cured in an oven at 300°C for 30 minutes.

In the case of application to screws, the compositions were applied by dip-spinning and then cured under the same conditions as for the panels.

The observed salt spray resistance results according to the ISO 9227 standard are given schematically in the following table:

TABLE 4

PRODUCT	SUBSTRATE	Coating weight**	Salt spray resistance*	
			Without MoO_3	With 2% MoO_3
Aqueous GEOMET®	Panels	32	288	> 840
Aqueous GEOMET®	Screws	30	144	504
DACROMET®	Screws	24	600	744

* Number of hours of exposure to salt spray before red rust appears.

** grams per square meter of coated surface, the thickness of the coatings are comprised between approximately about 6μm and about 8μm.

It is therefore apparent that introducing molybdenum oxide MoO_3 into compositions in aqueous phase, GEOMET® or DACROMET® containing particulate zinc, improves the salt spray resistance of the said compositions very substantially.

Another aspect of the invention consists in adding an alkaline silicate to the composition in an amount comprised between 0,05 % to 0,5 % by weight.

The addition of alkaline silicate, for example sodium silicate, surprisingly enhances the film cohesion in a worthy way.

This is particularly illustrated in the following comparative example given in Table 5.

EXAMPLE 3

In this example, the cohesion is evaluated by applying a transparent adhesive paper on the coating surface and by quick pulling off. The cohesion is evaluated according to a scale from 0 (complete pulling off of the coating film) to 5 (no pulling off at all of the coating film).

TABLE 5

Raw materials	Composition without silicate (concentrations in %)	Composition with silicate (concentrations in %)
Deionized water	38,13	37,96
Dipropylene glycol	10,08	10,08
Boric acid	0,64	0,64
Sympéronic NP4®	1,48	1,48
Sympéronic NP9®	1,61	1,61
Silane A187®	8,47	8,47
Zinc 31129/93	31,48	31,48
Aluminium CHROMAL VIII®	4,98	4,98
Schwegofoam®	0,21	0,21
NIPAR S10®	0,7	0,7
AEROSOL TR70®	0,52	0,52
MoO_3	1	1
Silicate of sodium grade 42	0	0,17
Xanthan gum (1)	0,7	0,7

(1) Thickening agent in order to control the viscosity of the composition during application

The composition is applied onto steel panels which have previously been degreased, with a Conway rod, in order to obtain a weight of a coating layer of 30 g/m^2. The plates are then cured under the same conditions as previously described.

They are then submitted to the salt spray test according to ISO 9227 and to the cohesion test. The results are shown in following Table 6.

TABLE 6

	Without alkaline silicate	**With alkaline silicate**
Salt spray (number of hours before appearance of red rust)	694	720
Cohesion	1/5	5/5

This table shows that even if the resistance to the cohesion is not significantly modified, the cohesion on the contrary, is highly improved.

CLAIMS

1. Use of MoO_3 as an agent for enhancing the anti-corrosion properties of an anti-corrosion coating composition based on a particulate metal containing zinc or a zinc alloy in aqueous phase.

2. Use according to Claim 1 for improving the effectiveness of the sacrificial protection exerted by the particulate metal, preferably used in a lamellar form.

3. Use according to Claims 1 or 2, characterized in that the anti-corrosion coating composition contains from 30 % to 60 % of water by weight.

4. Use according to one of Claims 1 to 3, characterized in that the anti-corrosion coating composition contains a silane-based binder, preferably carrying epoxy functional groups.

5. Use according to one of Claims 1 to 4, characterized in that the molybdenum oxide MoO_3 is in an essentially pure orthorhombic crystalline form, having a molybdenum content greater than approximately 60% by mass.

6. Use according to one of Claims 1 to 5, characterized in that the molybdenum oxide MoO_3 is in the form of particles having dimensions of between 1 and 200 μm.

7. Use according to one of Claims 1 to 6 characterized in that the anti-corrosion coating composition contains a silicate of sodium, potassium or lithium, preferably in an amount comprised between 0,05 % and 0,5 % by weight.

8. Anti-corrosion coating composition for metal parts, characterized in that it comprises:
   - at least one particulate metal;
   - an organic solvent;

- a thickener;
- a silane-based binder, preferably carrying epoxy functional groups;
- molybdenum oxide (MoO_3);
- possibly a silicate of sodium, potassium or lithium, and ;
- water.

9. Anti-corrosion coating composition for metal parts according to Claim 8, characterized in that it contains from 0.5% to 7% and preferably approximately 2% by weight of molybdenum oxide (MoO_3).

10. Anti-corrosion coating composition for metal parts according to Claim 8, characterized in that it contains from 10% to 40% by weight of at least one particulate metal.

11. Anti-corrosion coating composition for metal parts according to one of Claims 8 to 10, characterized in that the particulate metal is chosen from zinc, aluminium, chromium, manganese, nickel, titanium, their alloys and intermetallic compounds, and mixtures thereof.

12. Anti-corrosion coating composition for metal parts according to Claims 8 to 11, characterized in that the particulate metal is chosen from lamellar zinc and/or lamellar aluminium, and preferably comprises lamellar zinc.

13. Anti-corrosion coating composition for metal parts according to Claims 8 to 12, characterized in that the organic solvent is present in an amount of 1% to 30% by weight with respect to the total composition.

14. Anti-corrosion coating composition for metal parts according to Claim 12, characterized in that the organic

solvent is a glycol ether, in particular diethylene glycol, triethylene glycol and dipropylene glycol.

15. Anti-corrosion coating composition for metal parts according to Claims 8 to 14, characterized in that it contains from 0.005% to 2% by weight of a thickening agent, in particular of a cellulose derivative, more particularly hydroxymethylcellulose, hydroxyethylcellulose, hydroxypropylcellulose, hydroxypropylmethylcellulose, xanthan gum or an associative thickener of the polyurethane or acrylic type.

16. Anti-corrosion coating composition for metal parts according to one of Claims 8 to 15, characterized in that it contains from 3% to 20% by weight of silane.

17. Anti-corrosion coating composition for metal parts according to one of Claims 8 to 16, characterized in that the silane comprises γ-glycidoxypropyl-trimethoxysilane.

18. Anti-corrosion coating composition for metal parts according to one of Claims 8 to 17, characterized in that the organic solvent furthermore contains up to approximately 10% by weight of white spirit.

19. Anti-corrosion coating composition for metal parts according to one of Claims 8 to 18, characterized in that it contains approximately 30% to 60% by weight of water.

20. Anti-corrosion coating for metal parts, characterized in that it is obtained from a coating composition according to one of Claims 8 to 19 by spraying, dipping or dip-spinning, the coating layer being subjected to a curing operation preferably carried out at a temperature of between 70°C and 350°C.

21. Anti-corrosion coating for metal parts according to Claim 20, characterized in that the curing operation is carried out for approximately 30 minutes.

22. Anti-corrosion coating for metal parts according to Claim 20, characterized in that prior to the curing operation the coated metal parts are subjected to a drying operation, preferably at a temperature of around 70°C for approximately 20 minutes.

23. Anti-corrosion coating for metal parts according to one of Claims 20 to 22, characterized in that it is applied to the metal parts to be protected with a thickness of between 3 and 15 μm and preferably between 5 and 10 μm.

24. A coated metal substrate provided with an anti-corrosion coating according to one of claims 20 to 23.

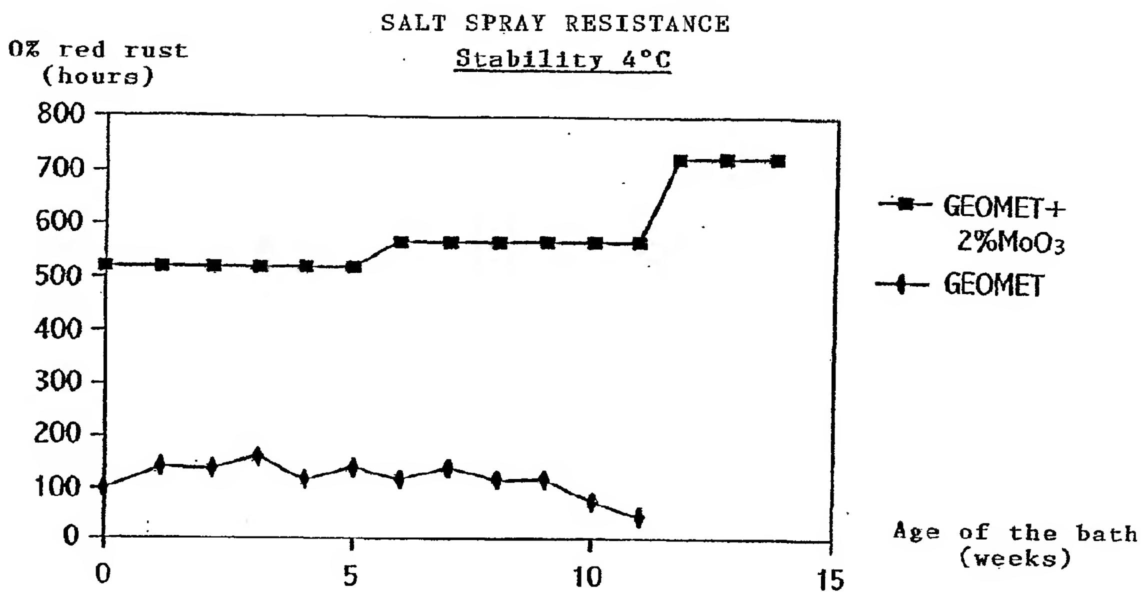
SALT SPRAY RESISTANCE
Stability 4°C
0% red rust (hours)
800
700
600
500
400
300
200
100
0
0
5
10
15
GEOMET+ 2%MoO3
GEOMET
Age of the bath (weeks)

FIG.1

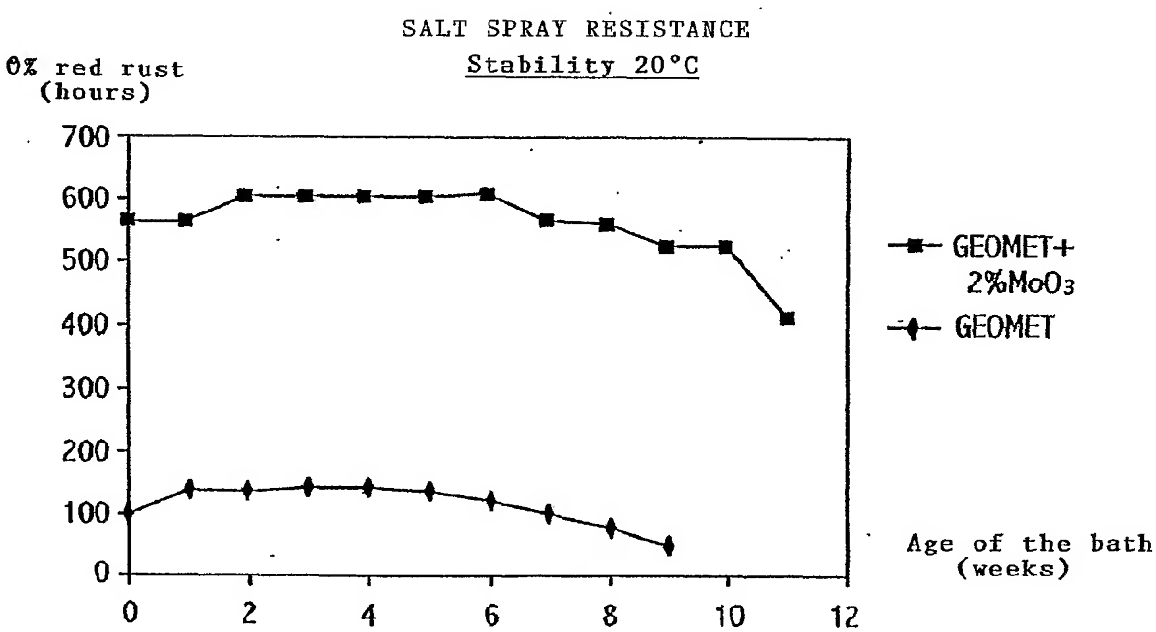
SALT SPRAY RESISTANCE
Stability 20°C
0% red rust (hours)
700
600
500
400
300
200
100
0
0
2
4
6
8
10
12
GEOMET+ 2%MoO3
GEOMET
Age of the bath (weeks)

FIG.2